OFF-CHANNEL SPAWNING AND REARING

Description

Since 1980, salmon-habitat enhancement programs in British Columbia and Washington State have given serious attention to the development of off-channel spawning and rearing habitat.[1] Projects have included restoration and modifications to river floodplain swales, abandoned side channels, and floodplain channels along steep terrace bluffs, all in order to increase spawning and rearing habitat. P. N. Peterson and L. M. Reid describe three types of habitat within a river floodplain: overflow channels, percolation-fed channels and wall-based channels.[2] Overflow channels are very active and prone to frequent flooding. Percolation channels are protected somewhat from flood flows and have the benefit of providing winter and summer refuge for juvenile fish and spawning habitat for adult fish. Wall-base channels often sit high in the river floodplain and are protected from flood flows and have been developed mainly as overwintering habitat for juvenile coho and trout.

Typical Application

Off-channel spawning and rearing areas are intended as mitigation for other projects that confine a channel (e.g.; bank protection, bridges) and as habitat restoration. Rearing habitat can also be gained by providing access for juvenile fish to existing off-channel ponds.

Often, bank protection projects harden the bank of a river and do not allow for natural channel meandering and thereby the creation of new floodplain channels. Construction of off-channel spawning and rearing habitat may provide mitigation for the future loss of this habitat type, or lost opportunity. Enhancing spawning and/or rearing habitat by developing groundwater-fed channels can result in significant production of coho and chum salmon.[3] If designed correctly, the lifespan of many of these channels can reach 20 years.

Variations

The primary objective in establishing a groundwater or spring-fed channels is to provide quality habitat for spawning and/or rearing. The proportion of the site used to meet a particular life history requirement can vary. It is site- and species-specific and should be based on mitigation requirements or, limiting factors to fish production in the watershed, and target species of fish. Some sites are allocated and designed solely to function as spawning sites, whereas other sites may incorporate juvenile rearing and adult holding habitat into the design. Numerous variations are possible with this type of enhancement project relative to site conditions and biological considerations.

Percolation-fed and Wall-Based Channels

Overflow channels are flood swales that are directly connected to the main river channel during high flows. Fish habitat associated with overflow channels is often unstable and typically prone to flooding and channel shifting. On the other hand, periodic floods through these channel can help maintain their productivity.

Percolation-fed channels. “perc channels,” are relict river and/or flood channels and are supplied by water that percolates as local groundwater from the river. They are usually better protected from floods and can provide ideal sites for spawning habitat enhancement and also provide winter and summer refuge for juvenile fish.

Wall-based channels can be groundwater fed but are often fed from springs or surface water from the adjacent terrace. They are usually higher in elevation relative to percolation-fed channels. Wall based-channels can often be enhanced to provide excellent rearing and overwintering habitat for certain species of juvenile salmonids.[4] These are shown schematically in Figure 6-1.

Figure 6-1. Natural Floodplain Channels

Methods and Design

Pre-Design

The following pre-design components are important to the development of successful off-channel habitat.

Site Selection and Inventory

The site might be selected from an inventory of site opportunities. Such an inventory should be conducted as part of watershed restoration planning or flood hazard management planning. Potential sites should be identified from aerial photos and USGS quad maps. Confirm potential sites by conducting a field survey, and identify any swales or depressions within the floodplain that are protected from frequent river flooding but appear to be deep enough to be near groundwater. (Refer to Chapter 3, *Reach Assessment* for further discussion of associated concerns.)

Identify and characterize nearby surface water sources. Identify likely areas in the main channel where the side channel flow can discharge into to attract fish to the site. The preferred location for a channel outlet is at a point where the channel approaches a terrace at the downstream end of a bend. At these locations, a natural river pool is often present to provide holding area and a transition into the side channel, and the location is most protected against closure by river bar deposits. These areas can also be created or enhanced by placing scour structures such as boulders or debris jams the channel outlet. The following describes the minimum effort required for an assessment of off-channel habitat opportunities.

Survey

Survey river water surface elevations upstream, adjacent to, and downstream of the proposed channel site. Record elevations of any surface water within the project area. Record recent high water marks, and estimate the return period based on past records. Set elevation reference points at the three locations, and tie the elevations together with a survey that includes elevation reference points for other fieldwork on the project site. For off-channel rearing ponds above the river flood plain, measure the proposed pond elevation relative to the access channel to determine the type and magnitude of channel modifications to ensure fish passage.

Evaluate Percolation Capabilities

The amount of percolation flow may determine the success of the project. Observe and evaluate soil characteristics and percolation capabilities. Dig test pits and perform percolation tests and water chemistry tests to determine soils, the potential of groundwater flow, and water temperature and quality. Record descriptions of the soils and survey the elevation of soil strata in the test pits.

Pump tests may be necessary to more accurately predict percolation rates. Analytical hydrologic methods are not available for spring flows; therefore, direct flow measurements should be made for a period of a year. A flow measuring weir can be installed but be aware that a slight change in water surface elevation can significantly change the volume of measured flow.

To accurately quantify groundwater-flow potential, an extensive aquifer test with at least several high-capacity wells and a long period, high-capacity pump test would be required. Such a test is not practical for this scale of project. A suggested alternative is to use parameters that indicate the relative potential among sites.

The Washington Department of Fish and Wildlife has developed a simple pump-test method. This pump test procedure simplifies the description of the groundwater by making the assumption that the water is unconfined. Restated, the aquifer has no impermeable boundaries. This method calculates relative aquifer permeability and relative aquifer supply rates.

Water is pumped from a test pit excavated by backhoe. Two parameters are used to analyze the groundwater potential: drawdown index and apparent velocity. The drawdown index is the pump rate divided by the drawdown rate, and the apparent velocity is the pump rate divided by the wetted area of the test pit. These parameters have been measured for 12 different projects, and comparative ratings have been developed.[5] Piezometers should be installed in the test pits and at additional sites along the proposed channel alignment.

Monitor Water Levels

River and groundwater levels and/or flows should be monitored during a wide range of river flows (at least three per monitoring site) and seasons. This usually requires a period of one year to cover winter and summer groundwater levels. These measurements can then be used to determine channel-control elevations, the depth of excavation and the potential of backwater effects from the river downstream.

For groundwater fed channels, the design of the channel elevation requires balancing the optimum water surface elevation for maximum groundwater flow against the potential that the channel will be backwatered too frequently from the river mainstem. Percolation flow, and therefore upwelling intergravel flow, is reduced when the channel is backwatered. The channel should operate most of the time without backwater effects from the river unless strong upwelling is expected to continure. The channel should be designed to not lose surface flow during summer months.

Once the design elevation is selected at the upstream end of the channel, the gradient of the channel can be selected. Log or plank weirs are usually installed to provide water depths throughout the channel between 0.7 to 3.0 feet. Channel depth is often species specific. Water level controls should be designed with design drops less than six inches to ensure passage for juvenile fish and to minimize loss of flow around the structure. Since the structures are built in a porous bed, it is often difficult to maintain flow over a water control structure that is higher. Water level controls such as log weirs need to be sealed with an impervious geotextile material to prevent loss of flow over the control and loss of fish passage there.

Generally, channel widths are in the range of eight to 20 feet and may be controlled by the excavation equipment to be used. Cost is directly driven by channel width.

Physical Habitat

Physical habitat features such as spawning gravel and woody debris should be incorporated into the design. Exposed gravel in the channel may be used or processed material may be imported. Many channels have provided successful spawning habitat using existing substrate. Evaluate the presence and quantity of potential spawning gravel during excavation of the initial project test pits. It may be economically viable to screen gravel from the overburden for use as spawning bed material. During construction of the channel, a layer of sand will likely accumulate on the gravel bed. It may have to be cleaned with a gravel-cleaning machine.

Cover structures should be located throughout the channel to provide refuge for adult and juvenile fish. Intermittent deep pools can be provided with cover for adult fish holding. Riparian structure should be built into the banks of the channel.

Water Supply

A channel that is fed primarily by groundwater flow provides a more stable environment for incubation and rearing than does a channel that relies solely on surface flow. Flow conditions and water temperatures are more consistent and predictable in channels fed by groundwater. Furthermore, groundwater-fed channels run warmer and clearer in the winter, providing better prey production and feeding opportunities, and a less harsh overwintering habitat.

A hydraulic gradient is created when a channel or pond that is excavated into the water table with the channel outlet and water level control elevation below the static water level. This hydraulic gradient controls the amount of surface water flow and is an important parameter in the success of a project. The gradient has much more influence than does the area of the channel or the depth of the channel bed. The amount of flow can be a controlling factor for adult usage and juvenile recruitment. Furthermore, the amount of inter-gravel flow is also closely related to egg-to-fry survival.[6] The quantity of groundwater flow is important, so it is desirable to make pre-project estimates of the flow potential.[7]

Physical and Biological Effects

A carefully designed channel in an appropriate site can provide spawning and year-round rearing habitats. Furthermore, groundwater channels are often protected from frequent flooding. This stability enhances the success of the project. However, catastrophic flow events that reach the channel can headcut through to the river mainstem and encourage avulsions. These floods can potentially alter habitat conditions, scour the streambed and physically destroy incubating eggs.

An excavated channel can affect the local groundwater level. There is a potential that wetlands can be drained and vegetation characteristics of the floodplain can be affected.

Mitigation Requirements for the Technique

This technique is typically used as a form of mitigation for lost or degraded spawning and rearing habitats. Mitigation for construction-related impacts or impacts to wildlife might be required.

An excavated channel can affect the local groundwater level. There is a potential that wetlands can be drained and vegetation characteristics of the floodplain can be affected. Those impacts can be roughly estimated with an accurate assessment of groundwater conditions and anticipated changes.

Restoration and Mitigation Benefits Provided

Use of this technique may have significant restoration or mitigation potential in watersheds where off-channel rearing and/or spawning are limiting factors to overall fish production or where mitigation is needed for lost opportunity. Creating successful spawning and incubation habitat can result in production of many generations of fish. Once successful, the stability and longevity of the project are central to the continued use of the project.

Risk and UncertaintyRisk to Habitat

Risks to habitat associated with this technique are low primarily because the work is done out of the main river channel and often in what is initially an upland area. There are risks of beavers changing the channel control elevation and the channel or pond becoming contaminated with sediment. There is a risk of stranding fish if elevations and flows are not accurately estimated, and surface flow is lost from portions of the project. Over time, leafy material from trees and fine sediment may accumulate and limit productivity or fish passage. These processes are usually part of the natural evolution of side channels. Some maintenance is needed to ensure continued operation at an optimum sole-purpose habitat.

There is also some risk when excavating in the floodplain that major shifts in the river could capture the channel during a large flood. The presence of the excavated channel might increase that risk. The site assessment and project design should evaluate this risk and accommodate it. Separation of the constructed channel from the river channel will reduce risk of avulsion. Constrictions made of boulders and/or debris within a constructed side channel can control how much flow it can pass and therefore the risk of avulsion. Constructed spillways in areas where floodwaters will enter the channel can help lessen the risk of headcuts forming at those places. See the techniques on floodplain roughness, floodplain drop structures, flow spreaders, and buffer management for ideas that can supplement channel construction to manage risk.

Reliability/Uncertainty of Technique

This technique, while proven successful, does rely on the assumption that a consistent and reliable source of groundwater is available. Appropriate site assessment as described here can minimize that uncertainty. Changes in land use should be kept in mind as they may alter groundwater dynamics.

Construction Considerations

Off-channel spawning habitat is usually constructed out of the active river channel and therefore requires less attention to factors that complicate construction in sites with moving water. If a channel is to be constructed in a surface water channel or in a spring channel with substantial flow, a thorough plan for project sequencing and care of the water must be developed. It might include temporary closure berms to isolate work areas, pumping water onto the forest floor or settling basins, and substantial filter devices to clean water that will discharge to the main river. Factors such as access, materials availability, equipment and labor, and sediment control are must be considered. Further discussion of these elements is provided in Appendix 13, *Construction Considerations*. Clean and appropriately sized spawning gravel is critical to the success of a groundwater fed spawning channel. Washed, rounded rock, generally 0.25 to 3.0 inches in diameter, provides ideal spawning habitat for many salmonids in the Northwest. Angular or crushed gravels should never be used as spawning substrate. Specific spawning gravel mixtures are included in the technique *Spawning Habitat.*

If the channel sub-base material is sandy or clayey, a gravel filter or geotextile blanket is often required to support imported spawning gravel. Additionally, special low bearing pressure equipment may have to be used for at least part of the excavation. Any debris should be anchored to accommodate large fluctuations in river water levels that backwater the channel.

Timing Considerations

Timing considerations are less of an issue in the establishment of off-channel habitat because the projects are usually somewhat removed from nearby bodies of water. Construction should be conducted when potential impacts to migrating or spawning fish are minimized. Additionally, construction should occur during seasons of low groundwater levels to facilitate Construction.

Cost

Cost is highly variable in spawning and rearing enhancement projects. Location of spoil piles, availability and delivery of gravel and large, woody debris, and site access are the primary factors that result in variable costs. One option used by the Washington Department of Fish and Wildlife to obtain spawning substrate is to sort gravels near the site. This technique involves the use of a mobile sorting operation located within close proximity to the project site. This technique significantly reduces delivery costs. Using on-site materials, construction costs may range from as little as $6 to $8 per cubic yard of material excavated, which includes bed controls, habitat structures and revegetation. However, imported gravel may cost $40 to $60 per cubic yard.

For further discussion of costs associated with off-channel spawning, refer to Appendix 12, *Cost of Techniques*, which describes costs associated with wood materials and complementary project components, such as creation of large, woody debris jams.

Operations and Maintenance

Maintenance is minimal with this type of project, although fine sediment and organic debris may gradually accumulate in the gravel bed. Periodic cleaning of gravel and/or supplementation with new gravel may be required to maintain or restore full habitat potential.

Monitoring Considerations

Biological monitoring provides the ultimate measure of project success. Annual spawner counts are the most direct measure of project success. Trapping of juvenile fish entering and leaving a site will be necessary to evaluate the rearing use of a channel. For a comprehensive review of habitat monitoring protocols, see *Inventory and Monitoring of Salmon Habitat in the Pacific Northwest – Directory and Synthesis of Protocols for Management/Research and Volunteers in Washington, Oregon, Idaho, Montana, and British Columbia*.[8]

In addition to biological monitoring, the monitoring of physical conditions is important to the documentation of project success. Periodic flow measurements in the channel will determine whether the flow is constant or diminishes over time. Analysis of sediment in the gravel bed can be used to evaluate its quality over time. An evaluation of headcut-prevention measures should be done after large floods occur that are high enough to enter the channel.

Examples

Site Example

The Washington Department of Fish and Wildlife has constructed a number of groundwater channels in recent years. Good example projects that incorporate the latest design information include Young's Slough, Nolan Channel, and Peterson Pond on the Hoh River in Jefferson County; Rainier Channel on the Bogachiel River in Jefferson County; and Taylor Channel, Park Slough and Park Slough Extension on the Skagit River in Skagit County.

Description

Photographs

References

[1]Bonnell, G. R. 1991. Construction, operation and evaluation of groundwater-fed side channels for chum salmon in British Columbia. American Fisheries Society Symposium 10:109-124.
and
Cowan, L. 1988. Physical characteristics and intragravel survival of chum salmon in developed and non-developed groundwater channels in Washington. Washington Department of Fisheries. Unpublished.
and
Powers, P. D. 1993. Structures for passing juvenile coho salmon into off-channel habitat. American Fisheries Society. Portland Annual Meeting.

[2]Peterson, P. N., L. M. Reid, 1984. Wall-based channels: Their evolution, distribution, and use by juvenile coho salmon in the Clearwater River, Washington. Proceedings of the Olympic Wild Fish Conference.

[3]King, D., R. Young. 1982. An evaluation of four groundwater fed side channels of the East Fork Satsop River - Spring 1985 outmigrants. Washington Department of Fisheries. Technical Report 90.

[4]Cederholm, C. J., W. J. Scarlett, N. P. Peterson. 1988. Low-cost enhancement technique for winter habitat of juvenile coho salmon. North American Journal of Fisheries Management. Vol 8. No. 4.

[5]Powers, P. D. 1992. “Draft in Progress”. Hydraulics of groundwater-fed spawning channels and rearing ponds. Washington State Department of Fish and Wildlife. Habitat Program

[6]Althauser, D.R. 1985. Groundwater-fed spawning channel development in the Pacific Northwest. Washington State Department of Fish and Wildlife. Habitat Program

[7]Powers. 1992.

[8] Johnson, D. H., N. Pittman, E. Wilder, J. A. Silver, R. W. Plontnikoff, B. C. Mason, K. K. Jones, P. Roger, T. A. O’Neil, C. Barrett. 2001. Inventory and Monitoring of Salmon Habitat in the Pacific Northwest – Directory and Synthesis of Protocols for Management/Research and Volunteers in Washington, Oregon, Idaho, Montana, and British Columbia. Washington Department of Fish and Wildlife, Olympia, Washington. 212 pp.